

TIME UNITS TO BE USED IN THE YELLOWFIN VPAS

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SUMMARY

This paper analyzes the choice of time intervals to be used in the Virtual Population Analysis (VPA) for yellowfin tuna. The VPA analyses used for yellowfin tuna were usually based on quarterly time intervals, when most other stock assessments are conducted on yearly intervals. The choice of this short duration was based on the short life of the species, its high mortalities (natural and fishing) and the marked seasonality of the fisheries. The present paper reviews the justifications for this use of quarterly intervals, comparing the results of VPA done on a quarterly and on a yearly basis. The analysis confirms that serious potential bias may outcome from the use of yearly intervals, when shorter intervals are always better. As those quarterly (or monthly) data are available in the ICCAT yellowfin data base, it is recommended to run all the yellowfin VPA using time intervals as short as possible, at least quarters and possibly months. The flexible ADAPT software which allows a tuning of the VPA to external abundance indices, should then be developed to handle this general problem of short living species with high Z exploited with seasonal fisheries.

RESUME

Cet article analyse le choix des intervalles de temps à employer dans les analyses séquentielles des populations ou Virtual Population Analysis (VPA). Les VPA réalisées sur l'albacore ont la plupart employé des intervalles trimestriels, alors que des intervalles annuels étaient employées pour la plupart des autres espèces. Le choix des intervalles trimestriels était basé sur la vie brève de l'espèce, ses mortalités naturelle et par pêche élevées et la forte saisonnalité des pêcheries. L'article revoit les justifications du choix des trimestres et réalise des VPA sur une base trimestrielle et annuelle, en comparant les résultats de ces deux analyses. Les analyses confirment que de sérieux biais peuvent résulter de l'emploi d'intervalles annuels dans les VPA. Comme les données de prises par âge relatives à l'albacore sont disponibles dans la base de données ICCAT sur une base mensuelle, il est recommandé que les VPA sur l'albacore utilisent des intervalles brefs, au moins trimestriels et possiblement mensuels. Le programme ADAPT qui permet classiquement de réaliser des VPA ajustées à des indices d'abondances mais qui ne travaille que sur un pas de temps annuel, devrait donc être modifié pour traiter de ce problème général des espèces exploitées par des pêcheries saisonnières et à fortes mortalités naturelle et par pêche.

RESUMEN

Este documento analiza la elección de los intervalos de tiempo que se deben emplear en los análisis secuenciales de poblaciones o Análisis de Población Virtual (VPA). En la mayor parte de los análisis de VPA llevados a cabo para el rabil se han empleado intervalos trimestrales, mientras que para la mayor parte de las restantes especies se han empleado intervalos anuales. La elección de intervalos trimestrales se basaba en la corta vida de la especie, su elevada mortalidad natural y por pesca y la marcada naturaleza estacional de las pesquerías. El documento examina las justificaciones de la elección de trimestres y lleva a cabo VPAs sobre base trimestral y anual, comparando los resultados de estos dos análisis. Estos análisis confirman que el empleo de intervalos anuales en los VPAs podría ser causa de serios sesgos. Dado que los datos de captura por edad referentes al rabil están disponibles en la base de datos de ICCAT en base mensual, se recomienda que los VPAs para el rabil utilicen intervalos breves, al menos trimestrales y si es posible, mensuales. El programa ADAPT, que permite llevar a cabo VPAs ajustados a índices de abundancia, pero que solo trabaja con intervalos anuales, debería por tanto modificarse para tratar este problema general de las especies explotadas por pesquerías estacionales con marcadas mortalidades, naturales y por pesca.

1. INTRODUCTION

The analytical work conducted by the ICCAT scientists working upon tropical tunas (yellowfin, skipjack and bigeye) has been conducted since 1973 (Fonteneau and Lenarz) using a quarterly time unit, when the yearly basis has been used for most other tuna species (albacore, bluefin and swordfish). The basis for this use of a quarterly unit of time for tropical tunas was:

(1) the limited duration of the exploited life, assumed to be approximately 6 years for yellowfin. It is obvious, when the duration of exploited life is short, for instance 1 or 2 years, that it may still be interesting to run the VPAs, but they must be done using short units of time, such as months. The case of intermediate durations, such as 6 years for YFT, needs further thinking.

(2) the marked seasonality of the fisheries: it is clear that when there is a marked seasonality in the fishery- such as for YFT- a short unit of time will give more realistic and detailed results to describe the real fishery, than a yearly interval. Because several major yellowfin fisheries take place at the beginning or the end of each year, it was assumed (by intuition) in the early VPA that the yearly intervals could introduce some bias in the VPA analysis, when the fishery had a strong seasonality and when the fishing mortalities were high. This very simple and intuitive rule was based on the arithmetics of stock sizes and fishery catches versus time intervals, and will be developed in chapter 2.

However this choice for quarterly intervals for yellowfin tuna has never been subject to a real critical review. This problem of time intervals in VPA needs further analysis in order to evaluate its real importance for the Atlantic yellowfin tunas, taking into account the parameters of the yellowfin stocks and fisheries: natural mortality of the species, exploitation rate of the stock and seasonality of the fisheries, as those three parameters are obviously of key importance in this problem.

This topic has been covered to some extent in various papers by Ulltang (1977), Sims and Parrack(1980) and Sims (1982), but always in general terms. Also, the methodological advantage in the present study on yellowfin is that both the quarterly and the yearly catch at age are known, this information allowing an easy comparison of the bias resulting from catches unevenly distributed in time. This topic will be covered in the chapter 3 of this paper.

As tuned VPA are presently conducted by the SCRS scientists using the ADAPT software on a yearly basis, this paradigm that the tropical tuna VPA's must be conducted on a quarterly basis must be carefully examined. If short time intervals should be used, the ADAPT type models should be adapted to be able to work with those short units of time, such as month or quarter.

Another point which will be examined (chapter 4) will be the potential bias using yearly intervals in the calculated fishing mortality trends, when the exploitation rate is increased.

2. SOME BASIC RULES UPON THE DECAY OF UNDERLYING POPULATIONS AND CATCHES.

Independently of the real catch at age data, it is always useful to remember some basic facts in the arithmetics of the cohort decay, under natural mortality and under fishing pressure. Those simple and basic mechanism can for instance be summarized in the following figure 1 which shows the monthly decay of the numbers in a cohort during one year, due to natural mortality.

In this example the initial number of fishes was 10000, suffering a $M=0.8$, natural mortality (commonly estimated for tropical tunas).

When a fishery is operating on this stock and catches 5000 fishes yearly, exploitation rate E of 50% (see figure 1), it can easily be seen that, if those 5000 fishes are taken during a single month, they can easily be taken at the beginning of the year (when the number of fishes in the cohort is maximum). The same number of fishes cannot be taken at the end of the year because the number of survivors is too low. At the middle of the year (for instance at the end of month 6) the catch could still be possible "arithmetically", but with a higher exploitation rate. This example corresponds to a quite high exploitation rate E of 50% (5000 fishes taken from a recruitment of 10000 individuals).

If the catch was only 100 fishes (lower exploitation rate), it becomes obvious that this small number can easily be removed during any of the 12 months.

Another important parameter in this kind of basic calculus will also be the natural mortality of the cohort: if the yearly natural mortality was only .2 instead of .8 (as shown in figure 1), it is obvious that our catch of 5000 individuals (same $E=.50$) can easily be removed from the cohort at any period of the year, under a similar exploitation rate.

This very simple arithmetic rules and the availability of quarterly catch at age data were the basis for the initial choice (Fonteneau and Lenarz 1974) of quarterly intervals for the VPA on Atlantic yellowfin tunas, as this species shows the three potential problems:

- 1- Marked seasonality of the fisheries with important catches at the beginning and the end of each year,
- 2- High M ,
- 3- High F , at least presently (and since the early eighties).

Those problems need further examination and analysis in relation with the yellowfin stock and fisheries.

3. SEASONALITY OF THE YELLOWFIN CATCHES:

3.1. OVERALL

The seasonality of the catches (and corresponding fishing mortalities) in the Atlantic yellowfin fishery is well shown for most cohorts as shown in the quarterly catch at age figure as estimated in June 1993 by the Tenerife working group on yellowfin tuna (table 1). This average quarterly catch at age table for yellowfin tuna for the entire Atlantic (period 1982-1991) was used to analyse this seasonality of the catch at age. The table 2 will give the numbers of fishes caught by age and year, and the figure 2 the average catch pattern by quarterly ages during the period 1982-1991.

The major seasonal events in the catch at age table are observed during two periods of the life cycle:

-1- During the recruitment phase at age 0, the catches are predominantly taken at the end of the year. An average of 86% was taken during the 2nd semester (and 50% during the last quarter) during the average period 1982-1991.

-2- For the adults, most of the catches are taken (every years) during the first quarter (spawning season). As an example, during the period 1980-1991 an average 61% of the yearly adult (age 4 and 5) catches in numbers were taken during the first quarter. This seasonality is very strong , as shown by figure 3, and observed constantly each year, with very few exceptions (for instance during the infamous 1984 Atlantic El Nino year, when the large yellowfin were not available to the purse seine fisheries because of a deep thermocline...).

The catches of intermediate ages (age 1 to 3) tend to be quite stable without a clear seasonal pattern (figure 2).

It must also be noticed that often the quarters are not homogeneous, as it is well shown by the 15 days catches of adult yellowfin (individual weight greater than 30 kg) by the eastern Atlantic purse seine fishery (figure 3). This figure shows for instance that a majority of the large yellowfin caught during the first quarter are taken at the end of this period (15th of February to the end of March or even at the beginning of April).

One can guess that such a marked seasonality should preferably be taken into account in the VPA analysis, as it was suggested previously by Ulltang 1977, Sims and Parraek 1980 and Sims 1982. This potential problem will be tackled in the following chapter.

3.2. DATA, HYPOTHESIS AND METHODS :

The cohort analysis or Virtual population analysis is a common mathematical tools based on the knowledge of the total catches by age. When the natural mortality is known (or estimated) and if one F_i (Fishing mortality at any age) or one N_i (population at any age) are known, the VPA allows to estimate by iteration all the N_i and F_i during the life of the entire cohort. This method allows a variable time interval in the analysis as proposed by Tomlinson 1970 (this method was the one employed in the present work). In its development by Fonteneau 1981, the method allows a forward and backward analysis which starts the analysis from any known underlying population at any age; this method will be used in the following work as it allows a simple comparison of the results.

Several VPA will be conducted on the average pattern of yellowfin catch at age during the period 1982-1991 (figure 2), under a realistic hypothesis of exploitation rate and natural mortality. This VPA will be conducted on a yearly and a quarterly basis during two critical stages with marked seasonality of the fisheries, the recruitment phase at age 0 (catches mainly during the fourth quarter) and the adult fishery at ages 4 and 5+ (catches mainly during the first quarter). Also a comparative cohort analysis will be conducted quarterly and yearly on each individual cohort recruited between 1975 and 1986 assuming for each cohort the levels of recruitment estimated by the Tenerife WG.

In this analysis, the following data and working hypothesis will be used:

(a) Data: Catch at age of table 1 and figure 2.

(b) Hypothesis:

(a) $M=.8$ at ages 0 and 1, and $M=.6$ at age 2+ (as assumed by the SCRS scientists).

(b) The underlying population (average recruitment) are at the levels estimated by the working group of Tenerife (1993) on yellowfin stock assessment.

(c) Method:

The cohort analysis will be conducted, starting in forward solution from the estimated recruitments at age 0 or 4.0, using quarterly and yearly intervals. In this analysis it will be assumed that the catches are randomly distributed within each quarter (no seasonality within the quarter); in this working hypothesis, the quarterly analysis provides the true value of the real F and N parameters. This "true" value can then be compared to its approximations calculated using a yearly total of the catch at age.

3.3-VPA ON AGE ZERO: AVERAGE CATCH PATTERN

The analysis was done for juveniles on the average catches at age zero (thousands) :

Average catch at age :

Quarter	C_i
1	0
2	546
3	1470
4	2013
Total	4029

The VPA were conducted in the hypothesis of the exploitation rates estimated by the Tenerife WG (with $M=0.8$). This level of recruitment was estimated at an average of 64.3 millions of fishes (Numbers at the beginning of age Zero).

The following results were obtained:

Average F 0-4q.	Quarterly analysis	.118
	yearly analysis	.095
	% of error on F_0	24 %
Survivors at end of age 0	Quarterly analysis	25.6M
	yearly analysis	26.2M
	% of error on N_0	2 %

This analysis shows that the use of the yearly intervals may lead to underestimate the average fishing mortality during the recruitment year (approximately 24%). Correspondingly, the underlying population surviving at the end of age zero may be overestimated by approximately 2%.

3.4. VPA ON AGE 4+ : AVERAGE CATCH PATTERN

The analysis was done for the adult catches on the average catches (in thousands) at age 4 and 5+ corresponding to a quarterly age between 17 and 24 quarters.:

Average catch at age :

AGE IN QUARTERS	C _i
17	346
18	112
19	64
20	50
Total	572
21	90
22	27
23	17
24	8
Total	142

The VPA were conducted in the hypothesis of the exploitation rates estimated by the Tenerife working group (with $M=0.6$): the recruitment to the average adult fishery at age 4.0, (after being exploited by the average 1980-1991 fishery) was at an average level of 1.194 millions fishes (surviving at the beginning of quarter 17).

The following results were obtained :

Average F 17-24 :	Quarterly analysis	0.894
	Yearly analysis	1.064
	% of error on F ₁₇₋₂₄	19.0%
Nb survivors end age 5	Quarterly analysis	59000
	Yearly analysis	42700
	% of error on N ₂₄	-28%

This analysis shows that the yearly intervals tend to overestimate the average fishing mortalities on adults of approximately 19% and to correspondingly underestimate the underlying population of adults of 4% (spawning stock), even in the ideal case when the recruited underlying population is perfectly known.

3.5. YEARLY AND QUARTERLY VPA ON THE COHORTS 1975 TO 1986:

All fully exploited cohorts fished during recent years have been analyzed by VPA with quarterly and yearly time interval during the entire life of each cohort. The recruitment estimated by the Tenerife WG have been kept as working hypothesis and used in the forward solution of the VPA. The table 3 gives the results, average fishing mortalities calculated in this comparative analysis.

It can be seen that on the average, the yearly VPA gives for most cohorts an overestimation of F. This over estimation of F is at an average level of 7.6% for the cohorts 1975 to 1986. However, when the errors are usually positive (10 cohorts on 12) with a maximum of 22% of excess in F (cohort 1983), the error upon F can also be slightly negative (-2.7% for the cohort 1985). This variability of the errors are probably due to the variability in the seasonality of catches between cohorts.

3.6. CONCLUSION

The potential errors from using yearly intervals instead of shorter ones, may not be of major importance but is clearly significant. It appears that the yearly analysis can introduce some significant bias in the results, for both the fishing mortalities and for underlying populations. Those biases are variable from one cohort to the other, depending of the seasonality of its catches. This potential bias also appear to be more critical at the end of the exploited life of the cohorts, when few individuals survive, when the exploitation rate is higher than for the juveniles (because of the spawning season) and when a definite and strong seasonality is observed in the fishery. The bias are probably higher when the exploitation rates are higher, as it will be shown in the following chapter.

4. UPON THE POTENTIAL BIAS WHEN THE EXPLOITATION RATE IS INCREASED.

Part of the problem in the VPA analysis, using too large and heterogeneous intervals, is often that the use of large yearly intervals may be acceptable when the stock is underexploited, but may become significantly biased for high fishing mortalities (as shown in chapter 2). In such a case, one can guess that both the absolute value of recent F (the more interesting) and the relative trends of F between the historical and present fisheries, may be biased. The following chapter will intend to briefly tackle this potential problem for yellowfin.

The case of the fishery for adults was chosen because of the importance of this group in the fishery and in any VPA.

First, a cohort analysis was conducted for the adult fishery (ages 4 and 5) on a yearly and quarterly basis on the average catch at age of the 1982-1991 period (fig.4), assuming the average recruitment and fishing pattern calculated by the WG of Tenerife.

Then, another set of cohort analysis was conducted (again on a yearly and quarterly basis), assuming the same seasonality in the fishery, but with a lower level of catches and the same average recruitment level. This level of reduced catches has been set by hypothesis to 1/3 of the average level of catches given by figure 2.

In each of those four calculations (2 levels of catches* 2 intervals of time), the fishing mortalities F were calculated.

The results are given in the following figure :

	UNDER EXPLOITED STOCK	PRESENT FISHERY (82-91)
Real Fishing Mortality Age 4+ (quarters)	.164	.894
Fishing Mortality at Age 4+ using yearly intervals	.182	1.064

This table shows that the fishing mortalities during the initial period were estimated with an excess of 11 % (when the stock was not heavily exploited). The error becomes more significant, at a level of 19% too high, for the present fishery, when yearly intervals are used.

Consequently, it was found that in the case of the adult fishery (predominantly 1st quarter) when the fishing mortalities are increased and when they are calculated using yearly intervals, the increasing trend of the fishing mortalities may be significantly overestimated by those yearly intervals, even in the optimal case when the underlying population is perfectly known.

5. FURTHER SIMULATIONS AND PROJECTIONS

Another problem, linked with the seasonality of the yellowfin fishery, is the validity of any further projections done (or simulations of the fisheries) using the results of the VPAs: a seasonal projection of the catches is necessary to mimic the marked seasonality of the fisheries. In the yellowfin fishery, where several gears are in activity, each one with its own seasonal pattern of catches, it is of major interest to keep track of those multi gears patterns, in the analysis of the past fisheries and in all the projections.

The quarterly (or monthly) VPA is the only way to obtain those seasonal F at age, based on the observed seasonality of the catches. In a highly seasonal fishery such as the yellowfin fishery, all simulations of the fishery and projected catches or catch rates should obviously take into account the seasonality of the various fisheries, in order to be realistic.

6. CONCLUSION

This analysis confirms the previous empirical choice by Fonteneau and Lenarz 1973 and the analytical conclusions by Sims and Parrack 1980, that:

"If the fishery is seasonal with heavy exploitation at one end of the year and if the natural mortality is high, then the relative error in stock size can be unacceptably large. If these conditions prevail, it is recommended that the VPA be performed on the basis of time units smaller than a year".

Quarterly units of time, or possibly month, should then be used in the yellowfin VPA, as the yearly intervals may introduce various bias in the results and several limitations in the further use of its results.

It is consequently recommended that ADAPT, the tuned VPA model successfully used by ICCAT scientists during recent years, should be developed to handle shorter intervals of time than the yearly intervals

presently used in this program. This development seems to be quite complex to handle, but it should introduce a general and significant benefit for all the tuna species with a short exploited life (due to high natural and fishing mortalities) and a marked seasonality of the fisheries, such as most tropical tuna species.

No potential negative impact from the model can be expected from the use of those shorter time units, which can only introduce better results from all future analysis.

Also, when many potential bias and uncertainties in the stock assessment cannot, for practical reasons (for instance the uncertainties in the level of age specific natural mortalities, etc...), be corrected, this present bias of the time interval durations used in the VPA is quite easy to correct. Also the ICCAT data base for tropical tunas is such that most of the size and age data are potentially available by monthly time intervals; this detailed data base should then be used entirely, instead of yearly totals of catch at age.

This practical problem should then be solved as soon as possible, as the shorter intervals will be better in most cases than the yearly intervals, especially for tropical tunas.

BIBLIOGRAPHY

- FONTENEAU A. and LENARZ W. 1974. Cohort analysis of the eastern Atlantic fishery for yellowfin tuna. Rec. Doc. Scient. ICCAT, Vol.2, pp57-77.
- GULLAND, J.A. 1965. Estimation of mortality rates. Annex to Arctic fisheries Working group Report. ICES. C/M. 1965, Num.3.
- SIMS S.E. and PARRACK M.L. 1980. The effects of unevenly distributed catches on virtual population analysis. Rec. Doc. Scient. ICCAT. Vol. 9, pp 26-39.
- SIMS S.E. 1982. The effects of unevenly distributed catches on virtual population analysis. J. Cons. Int. Explor. Mer; 40(1): 47-52.
- TOMLINSON, P.K. 1970. A generalization of the Murphy catch equation. J. Fish. Res. Bd. Canada 27, pp821-825.
- ULLTANG, O. 1977. Sources of errors in and limitations of virtual population analysis (cohort analysis). J. Cons. Int. Explor. Mer, 37(3): 249-260.

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